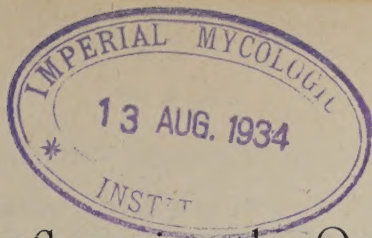


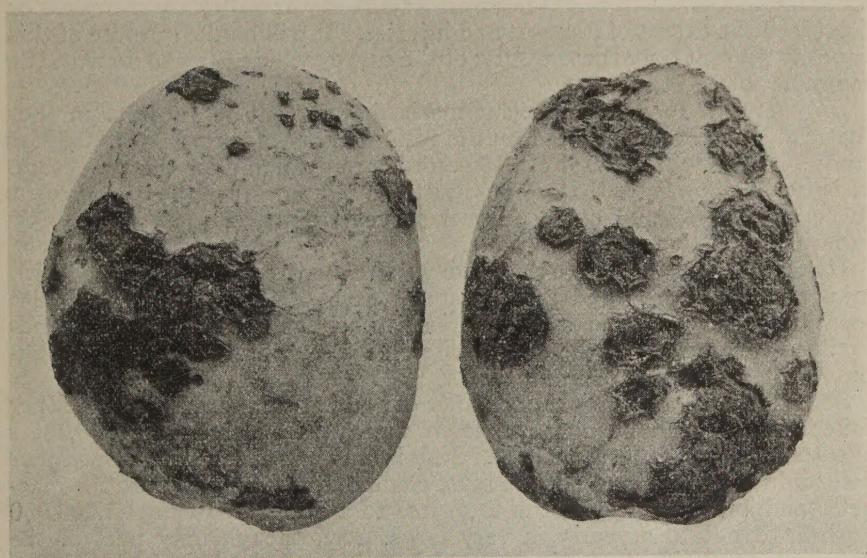
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FACTORS INFLUENCING THE OCCURRENCE OF POTATO SCAB IN NEW YORK

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During the potato-harvest seasons of 1931 and 1932, a field study was made to determine the potato-tuber defects on New York farms. At the same time data were obtained on the regions where the injuries occurred, on the proportion of tubers affected by diseases and injuries, and on the other influences which might have either directly or indirectly increased or decreased the extent of diseases and injuries. It will be the purpose of this paper to present only those results of the survey which have to do with the common potato scab.

Only a few influences can be summarized at present because the number that can be studied is limited by the total number of records available for study. At present, a total of 313 records are available for the two years. It is hoped, however, that some questions left uncertain by the present survey can be cleared up by further survey results, or more directly by experiments if this seems desirable.

It may be mentioned here that scab was frequently found associated with injuries by millipeds and gnats, though each of these pests was found separately; hence no one of the injuries can be regarded as strictly secondary. However, most of the deeper pits on scabby potatoes could be attributed to either gnats or millipeds.

Some idea of the relative importance of scab, as compared with the other tuber injuries, can be obtained from the average percentage of tubers affected by each of these (table 1). Scab is only one of several serious tuber defects in the State, and not the most common or damaging from the market standpoint. However, the total loss to a State producing 28,000,000 bushels of potatoes yearly is very large, even though only part of the potatoes listed with the various troubles are unmarketable.

TABLE 1. AVERAGE PERCENTAGE OF TUBERS AFFECTED BY VARIOUS DISEASE AND PEST INJURIES IN THE SURVEY OF 313 FIELDS, 1931 AND 1932

	Per cent
Clean.....	42.2
Rhizoctonia.....	23.9
Wireworms.....	17.2
Scab.....	13.1
Gnats.....	10.2
Millipeds.....	8.3
Flea beetles.....	1.8
Grubs.....	1.1

Trouble with potato scab is localized. If a map of the State, showing the distribution by counties (figure 1), is examined, a considerable and significant variation from one county to another is noticed. Generally there is more scab in counties where the soils contain larger amounts of lime, or, in other words, where the lime requirement for clover is low. Thus, little scab is found on Long Island or in the southern-tier counties in western New

York. More is found in Genesee, Monroe, Ontario, and Onondaga Counties. On the acid soils in the hill sections of Clinton County very little scab is found, but it is serious in the soils well supplied with lime, at lower altitudes.

In the survey, an effort was made to restrict each sample to a single soil type. However, the different types of soil were so numerous (about 88) that on most of them only a few records were obtained. For this reason no summary will be presented under the soil-survey type names but the soils have been grouped on the basis of texture and reaction, as indicated in table 2, in an attempt to show their relation to the occurrence of scab. The classification into alkaline (sweet) and acid (sour) soils is based on a field colorimetric test of the soil and subsoil to a depth of about three feet, as used in soil-survey practice; a soil is classified as alkaline if it shows an alkaline reaction anywhere to this depth. This classification into alkaline and acid soils presents the most striking differences in table 2, giving an average of 20.1 per cent scabby on the alkaline and 8.9 per cent scabby on the acid soils, with a difference of 11.2 per cent which is about five times its standard error and quite certainly significant. Not only is the difference between the general averages significant but also the differences between alkaline and acid heavy soils (16.3 ± 4.0) and between alkaline and acid medium soils (7.1 ± 3.4) are significant. In the light soils no difference was found in the amount of scab between the alkaline and acid soils. To state the results another way, no consistent difference in the amount of scab was found on different groups of alkaline soils classified on the basis of fineness. On the acid light soils there was consistently more scab than on the heavy or medium acid soils. When the alkaline and acid soils are averaged together, there is significantly more scab on the light soils. The differences between medium and heavy soils are small and not significant.

In addition to the field tests of the soil on which the classification into alkaline and acid soils was based, samples of the surface soil to a depth of six inches for hydrogen-ion determinations were taken. Each soil sample, like the samples of potatoes collected, was made up of twenty sub-samples, each taken as near as possible to the spot where the potatoes were dug. The readings were made electrometrically by the quinhydrone method. It would perhaps be expected that this method of making acidity readings directly on the surface soil would be more directly related to the amount of potato scab than field tests which include the deeper layers, and this seemed to be so (table 3) when the soils were cross-classified on these two factors.

In general, soils with acid subsoils have acid surface soils, but where they do not, the scab percentage corresponds with that expected on the basis of the pH of the surface soil; a corresponding statement can be made for the soils having alkaline subsoils.

An average of 23 per cent of potatoes were scabby in the pH group of soils from 5.45 to 7.4, as compared with 5 per cent in the pH group 4.3 to 5.44, and a difference of 18 per cent with a standard error of 2.07 which indicates that this difference is highly significant. Only a few soils fell within the pH group from 7.5 to 8.5. However, the potatoes on such soils had less scab. The average was 10.7 per cent, or a difference from the pH group 5.45 to 7.4 of 12.5 per cent, with a standard error of 5.15, indicating that this difference is significant (odds 65:1).

TABLE 2. RELATION OF TEXTURE OF SOIL TO AMOUNT OF SCAB

Classification as to texture	Alkaline subsoil		Average increases on alkaline over acid soils	Acid subsoil		All soils	
	Samples	Scabby potatoes		Samples	Scabby potatoes	Samples	Scabby potatoes
	<i>Number</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Number</i>	<i>Per cent</i>	<i>Number</i>	<i>Per cent</i>
Heavy soils:	29	21.8 ± 3.8*	16.3 ± 4.0	85	5.5 ± 1.2	114	9.6 ± 1.5
Silty clay loam							
Silt loam							
Shaly silt loam							
Stony silt loam							
Gravelly silt loam							
Increase in percentage of scabby potatoes on medium over heavy soils...		-5.8 ± 4.7			3.4 ± 2.3		1.9 ± 2.2
Medium soils:	43	16.0 ± 2.7	7.1 ± 3.4	72	8.9 ± 2.0	115	11.5 ± 1.6
Loam							
Shaly loam							
Gravelly loam							
Increase in percentage of scabby potatoes in light over medium soils....		6.9 ± 3.9			11.8 ± 5.0		10.5 ± 2.9
Light soils:	45	22.9 ± 2.8	2.2 ± 5.4	29	20.7 ± 4.6	74	22.0 ± 2.5
Very fine sandy loam							
Fine sandy loam							
Fine sand							
Sandy loam							
Gravelly sandy loam							
Stony fine sandy loam							
Gravelly fine sandy loam							
Totals.....	117			186		303	
Averages.....		20.1 ± 1.75	11.2 ± 2.13		8.9 ± 1.21		13.1 ± 1.03

*Standard errors are used in all tables. A difference to be significant (i. e. odds 20:1 or more) should be at least 2 times its error.

TABLE 3. PERCENTAGE OF POTATOES SCABBY ON SOILS CLASSIFIED ON THE BASIS OF PH OF THE SURFACE SOIL

pH of soil	Records	Scabby potatoes
	<i>Number</i>	<i>Per cent</i>
4.0 -4.4	8	1.8
4.5 -4.9	62	6.0
5.0 -5.44	95	5.0
Total.....	165	
Average.....		5.22 ± 0.76*
5.45-5.9	68	19.3
6.0 -6.4	33	26.4
6.5 -6.9	15	25.7
7.0 -7.4	17	30.6
Total.....	133	
Average.....		23.22 ± 1.93*
7.5 -7.9	12	11.3
8.0 -8.35	3	8.3
Total.....	15	
Average.....		10.67 ± 4.78*

Average differences

pH 5.45 to 7.4 over 4.0 to 5.44
pH 5.45 to 7.4 over 7.5 to 8.5

18.0 ± 2.07*
12.5 ± 5.15*

*Standard errors.

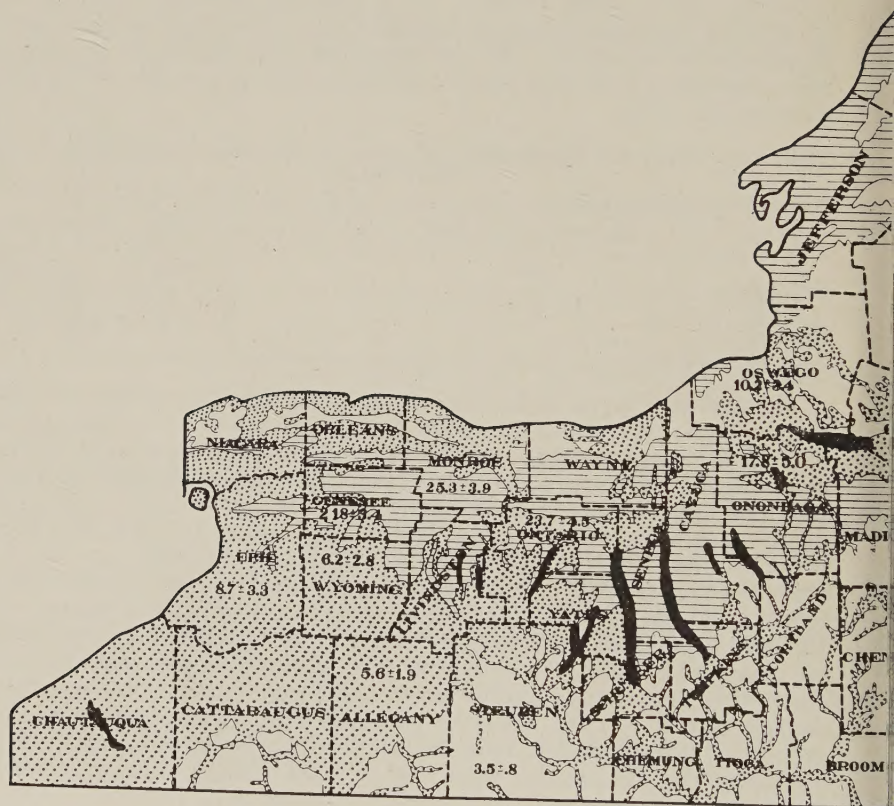
For some reason, in the parts of New York State covered by these surveys, there seems to be some relation between elevation and the occurrence of scab. Thus most of the high percentages of scab were found at elevations of 400 to 1200 feet above sea level (table 4). No doubt the relation is indirect and may very possibly be related to the distribution of soils with relatively high content of lime. It is notable that such soils are more common at the lower elevations around Lake Ontario and in the valleys of southwestern New York. At low elevations on Long Island the soils are acid and there is little scab, while a similar condition prevails on the hills in western New York.

TABLE 4. RELATIVE OCCURRENCE OF SCAB AT DIFFERENT ELEVATIONS IN NEW YORK STATE

Elevation above sea level	Records	Scabby potatoes
<i>Feet</i>	<i>Number</i>	<i>Per cent</i>
Unclassified.....	2	23.5 $\pm$ 19.5
0-399.....	67	9.0 $\pm$ 2.0
400-1199.....	133	21.3 $\pm$ 1.8
1200-2400.....	111	5.7 $\pm$ 1.1

The averages given so far have been based directly on the amounts of scab, with no corrections for other possible influences. The effect of some of these is clearly to reduce the size of the differences that would otherwise be obtained. Thus no account has been taken of the different varieties of potatoes but all were averaged together. An inspection of cross-classification tables reveals at once that the more susceptible varieties (Green Mountain and Irish Cobbler) are grown almost exclusively on the more acid soils where scab is less troublesome, while on the more alkaline soils the less susceptible varieties (Smooth and Russet Rurals) are grown. Fortunately some Rurals are also grown on acid soils so that there is some basis for comparison. Not only does this use of varieties of potatoes in places to which they are adapted tend to give smaller differences in scab at different degrees of acidity than would be expected if a uniform variety had been grown but it also tends to hide the differences between varieties in general averages. For this reason some use of cross classification or partial or multiple correlation, or a system of corrections, is necessary to make evident some of the differences that exist.

At the end of the first year's survey an effort was made to show by correlation methods the relation between the reaction of the soil expressed as pH and the percentage of scabby potatoes. Simple correlation was first tried, giving a coefficient of correlation of 0.34 ± 0.08 , which is clearly significant but which accounts for only a small part of the variability (about 11 per cent). A similar computation over the two years gives a coefficient of correlation of 0.36. But when the regression lines obtained from this simple correlation were plotted on a scatter diagram it was obvious that they did not very well represent the distribution and that no single straight line would be very satisfactory. Two straight lines were next tried by computing two correlation coefficients, one over the range of pH 4.5 to 7.0 giving 0.53 ± 0.07 and the other over the range of pH 6.6 to 8.5 giving -0.62 ± 0.14 . Both are significant and indicate an increase of scab with an increase in pH in the lower range of pH values, and a decrease



LEGEND

HIGH

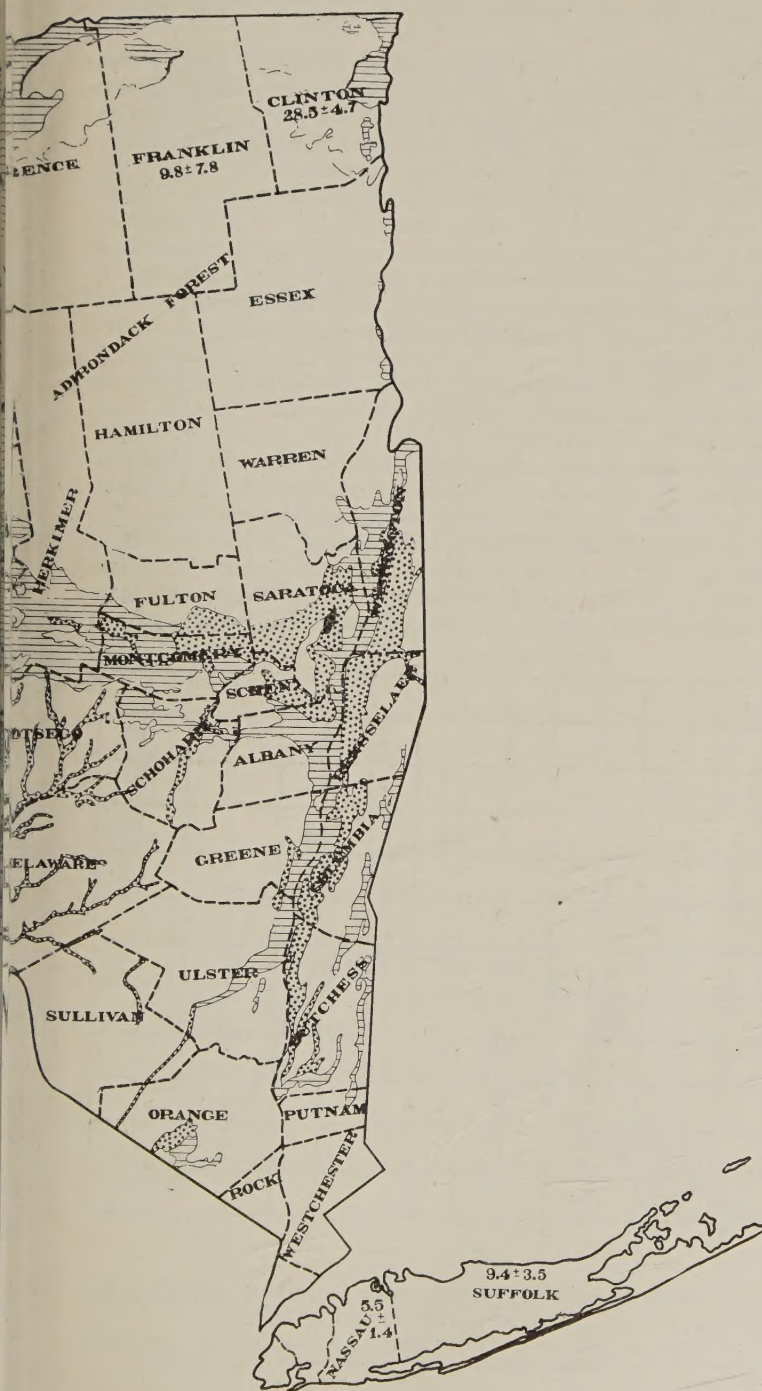
MEDIUM TO HIGH

LOW TO MEDIUM



FIGURE 1. INVERSE RELATION OF HIGH, MEDIUM, AND LOW LIME REQUIREMENT FOR RED CLOVER, INDICATED BY SHADING, TO THE AMOUNT OF SCAB ON POTATOES BY COUNTIES

The average percentages of scabby potatoes in the counties surveyed were: Allegany 5.6 ± 1.9, Clinton 28.5 ± 4.7, Erie 8.7 ± 3.3, Franklin 9.8 ± 7.8, Genesee 21.8 ± 3.4, Monroe 25.3 ± 3.9, Nassau 5.5 ± 1.4, Oneida 10.1 ± 5.5, Onondaga 17.8 ± 5.0, Ontario 23.7 ± 4.5, Oswego 10.2 ± 3.4, Steuben 3.5 ± 0.8, Suffolk 9.4 ± 3.5, and Wyoming 6.2 ± 2.8



in scab with increase in pH in the higher range. This has also been shown in another way in table 3.

In an effort to better represent the relation between pH and percentage of scabby potatoes by a continuous curve, the methods of Ezekiel (*Methods of Correlation Analysis*, 1930) were followed of drawing a free-hand curve guided by group averages and taking deviations of individual readings from this curve. These deviations were then corrected for variety of potatoes, kind of seed treatment, and acid and alkaline subsoils. These corrections were made only in the pH range from 5.6 up. Below this the corrections seemed to be too small to be important. After these corrections were made to the deviations they were again averaged and a new curve drawn. This whole process was repeated several times until the corrections became so small as to be negligible and no further improvement was made. This curve (figure 2) represents the relation between pH and percentage of scabby potatoes for White Rural potatoes with hot-corrosive-sublimate seed treatment on soils with alkaline subsoils, as derived from the first year's survey. The index of correlation is 0.86 ± 0.02 , which indicates that this curve, after the corrections mentioned above are made, accounts for about 75 per cent of the remaining variability. At the end of the second year's survey the deviations from this curve were included for each record. These deviations are used in the following tables, since in this way it is believed allowance can best be made for the variation in potato scab due to variations in acidity, without much additional computation, and thus differences due to other influences can be brought out more clearly.

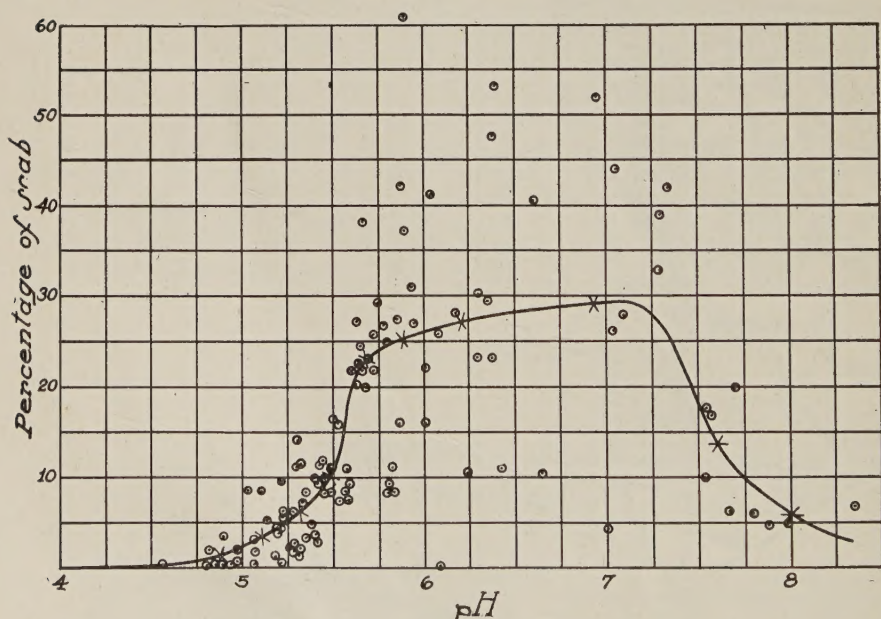


FIGURE 2. CURVE TO REPRESENT THE RELATION OF SCAB TO PH FOR SMOOTH-RURAL POTATOES ON SOILS WITH ALKALINE SUBSOILS, 1931

The dots represent percentage of scab in individual counts after corrections for reaction of subsoil, variety of potatoes, and kind of seed treatment. The X's represent group averages

Before turning to these other influences, it may be said that efforts were made to find some mathematical type of curve that would at least approximately express this relation. After various trials it was found that if the logarithm of the percentage scab were plotted as ordinates with pH as abscissas, the points could be fairly well represented by a parabola. The same result can more easily be obtained by the use of semi-log cross-section paper by plotting the percentage scab on the logarithmic scale and the pH on the plain scale in a perhaps more easily useful form. Such a curve is

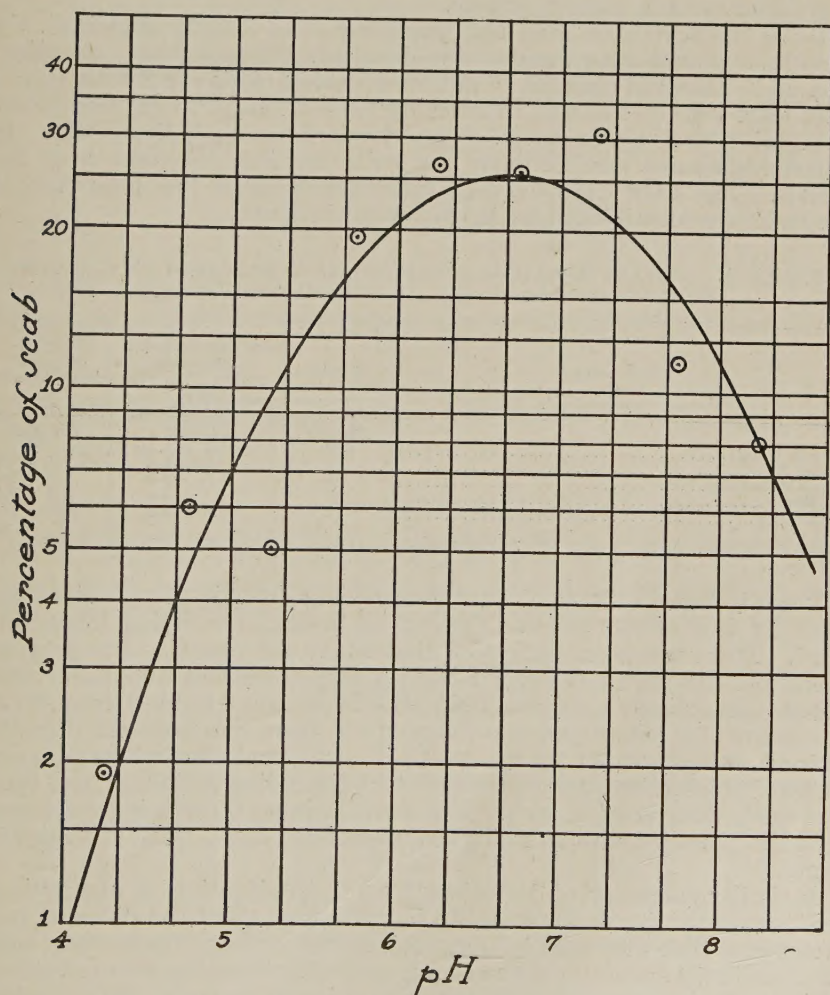


FIGURE 3. RELATION OF SCAB, ON A LOGARITHMIC SCALE, TO pH

The curve was obtained by fitting log scab of group averages for the two years and average pH to a parabola by the method of least squares

shown in figure 3 with the group averages from table 3 plotted. This curve represents an equation which may be written in the following form:

$(x-h)^2 = C(y-k)$ in which x is the pH, y the logarithm of the percentage of scabby potatoes. Of the constants, h is the pH at which the maximum scab occurs (about 6.6) and k the logarithm of the percentage scab at that point (about 1.43, equivalent to 27 per cent scabby) and C another constant (approximately -8.58) not so directly interesting. This curve varies considerably from the free-hand curve of figure 2 but is presented as an alternative approximation to the relation of pH to scab from which, however, the individual records differed widely.

Using the deviations from last year's curve, as already explained, the records of several other factors were classified. The results of a classification on the basis of varieties of potatoes (table 5) indicate Russet Rurals were least scabby, followed in order by Smooth Rurals, Cobblers, Green Mountains, and Up-to-Dates. The standard errors indicate that the Green Mountains and Cobblers are quite certainly different from the Rurals. Only a few Up-to-Date potatoes were found so that their place in the scale of susceptibility remains somewhat in doubt.

TABLE 5. AVERAGE DEVIATIONS IN PERCENTAGE OF SCAB FROM pH CURVE TO SHOW RELATIVE SUSCEPTIBILITY OF DIFFERENT VARIETIES

Varieties	Records	Average deviation in proportion scabby from pH curve	Average difference from Smooth Rurals
	<i>Number</i>	<i>Per cent</i>	<i>Per cent</i>
Smooth Rurals.	132	-1.3 ± 1.2	0
Russet Rurals.	37	-3.0 ± 2.8	-1.7 ± 3.0
Green Mountains.	80	5.7 ± 2.1	7.0 ± 2.4
Cobblers.	28	4.1 ± 2.4	5.4 ± 2.7
Up-to-Date.	6	9.3 ± 6.8	10.6 ± 6.9

Records were available of what the previous crops in the rotations had been for four or five years. Various methods of classifying these were tried. There was some indication that where sod preceded the potatoes there was less scab but beyond this no very consistent differences were noted. Accordingly a simple classification is presented (table 6) from which it appears that where potatoes followed sod there was less scab than the average as represented by the scab pH curve, and that where potatoes followed potatoes or other cultivated crops (including various grains) there was more than average scab. The increase in scab following cultivated crops as compared with following sod, though not large, seems to be significant.

A similar summary of deviations from a classification on the basis of seed treatment (table 7), seems to indicate that all of the different seed treatments that were used in any considerable number of cases show some decrease in the amount of scab as compared with those that were untreated. This result gives a rather more optimistic view of the value of the various mercury seed treatments than has been obtained in field experiments made in the sections of the State on soils with pH values favorable for scab. For this reason perhaps it should be regarded as questionable.

TABLE 6. AVERAGE DEVIATIONS FROM pH CURVE IN PROPORTION OF SCAB, CLASSIFIED ON BASIS OF PREVIOUS CROP

Previous crop	Sample	Average deviation in proportion scabby from pH curve	Average increase in scab following other crops as compared with sod
	Number	Per cent	Per cent
Unclassified.....	2	13.5 ± 16.1	
Sod.....	157	— 3.1 ± 1.1	0
Potatoes.....	88	5.4 ± 1.8	8.5 ± 2.11
Other cultivated crops.....	66	2.7 ± 2.2	5.8 ± 2.46

TABLE 7. AVERAGE DEVIATIONS IN PROPORTION OF SCABBY POTATOES FROM pH CURVE WHEN CLASSIFIED ON KIND OF SEED TREATMENT

Treatment	Samples	Average deviation from pH curve	Average difference in percentage of scab from untreated
	Number	Per cent	Per cent
Unclassified.....	21	—5.2 ± 2.4	—10.5 ± 2.8
Cold HgCl ₂ *.....	13	—9.8 ± 2.9	—15.1 ± 3.3
Hot HgCl ₂ *.....	41	—1.2 ± 2.1	— 6.5 ± 2.6
Calomel.....	6	— 1.1 ± 7.9	— 5.4 ± 8.0
Cold CHOHT†.....	2	2.3 ± 7.7	— 3.5 ± 7.8
Hot CHOHT†.....	6		
HgO‡.....	55	—1.2 ± 2.1	— 6.5 ± 2.6
Semesan Bel.....	40	—3.9 ± 2.1	— 9.4 ± 2.6
No treatment.....	129	5.3 ± 1.5	0
Total.....	313	0.60	

*HgCl₂ = corrosive sublimate, or mercuric chloride.

†CHOH = formalin.

‡HgO = yellow oxide of mercury.

From two years survey it is naturally not possible to show what effect temperature and moisture have on the prevalence of scab. For this purpose, surveys over a long series of years would be necessary. An attempt was made to determine the relative prevalence by cross-classifying into large pH groups for the two years (table 8), which seems to indicate clearly

TABLE 8. COMPARISON OF PERCENTAGES SCABBY FOR 1931 AND 1932 ON SOILS IN DIFFERENT pH GROUPS

pH of soil	1931		1932		Average difference
	Sample	Average quantity of scab	Sample	Average quantity of scab	
	Number	Per cent	Number	Per cent	Per cent
4.33-5.44	53	3.3 ± .9	112	6.2 ± 1.0	2.9 ± 1.3
5.45-7.49	61	18.7 ± 2.8	72	27.0 ± 2.6	8.3 ± 3.8
7.50-8.35	9	8.8 ± 2.3	6	13.5 ± 4.3	4.7 ± 4.9

Average departures from normal in New York

	1931		1932	
	July	August	July	August
Temperature.....	+3.1	+1.3	—1.8	+1.7
Rainfall.....	+1.46	—0.77	+0.72	+0.06

that scab was a little more serious in 1932 in each pH group as well as in the general average. An inspection of the average weather conditions for the State does not seem to offer any basis for explaining this difference.

Various other classifications were tried with these records, such as soil drainage, and kind, amounts, and methods of application of fertilizers, manures, and lime, but no definite conclusions could be reached on the basis of the present surveys. This may be owing to the small number of records in some of the classification groups.

CONCLUSIONS

In this survey, in which 313 samples of 100 tubers each, at different places, were examined, Rhizoctonia, wireworms, scab fungi, gnats, and millipeds were found to be the principal causes of potato-tuber defects. An average of 13.1 per cent of the potatoes were scabby but there was considerable variation from one farm to another and in different parts of the State. In several counties, the average of scabby potatoes, for all those examined, was more than 20 per cent, while in a number of others the average was less than 10 per cent. The scab percentages average high on the soils where the lime requirement for clover is low (figure 1).

When the records obtained are classified on the basis of field tests of the soil to a depth of three feet, those from fields with alkaline subsoils were more scabby, especially on the heavy and medium soils. On the light soils there were no significant differences.

When the classification was based on the pH tests of the surface soil, a better separation was obtained. Potatoes on soils from pH 4.3 to 5.4, had the least scab, more from pH 7.5 to 8.5, and most from pH 5.45 to 7.4. Curves are presented showing the approximate relation of percentage of potatoes scabby to the pH of the soil. Also, a tabulation is presented indicating that there is some indirect relation between elevation and the occurrence of scab-favorable soils in New York State. There was significantly more scab at elevations between 400 to 1200 feet than at lower and higher elevations.

Using deviations from the pH curve to avoid, so far as possible, effects due to pH, a classification based on varieties indicates the order from less to more susceptible to be Russet Rurals, Smooth Rurals, Cobbler, Green Mountains, and Up-to-Dates for the varieties commonly grown in the State.

In a similar way, it was shown that there was generally less scab where potatoes follow sod rather than potatoes or other cultivated crops.

Seed treatments apparently helped to control scab. There was a little more scab in 1932 than in 1931.